

## Hibernate second-level caching (2LC)

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You can use Infinispan as a second-level cache (2LC) with Hibernate to store all sessions from applications using the same session factory.

# Chapter 1. Using Infinispan as a second-level cache

Infinispan implements the SPI that Hibernate exposes to allow integration with the second-level cache (2LC). This means you can use Infinispan to store data from `Session` or `EntityManager` (JPA) operations.

The [Caching](#) chapter in the Hibernate ORM User Guide contains complete information about 2LC. This guide provides details about using Infinispan as second-level cache provider with Hibernate.

## 1.1. Adding dependencies

Applications running in environments where Infinispan is not default cache provider for Hibernate will need to depend on the correct cache provider version.

The Infinispan cache provider version suitable for your application depends on the Hibernate version in use:

### *Hibernate 5.3*

```
<dependency>
  <groupId>org.infinispan</groupId>
  <artifactId>infinispan-hibernate-cache-v53</artifactId>
  <version>${version.infinispan}</version>
</dependency>
```



Hibernate 5.2 is supported with Infinispan 9.2.x only.

### *Hibernate 5.2*

```
<dependency>
  <groupId>org.infinispan</groupId>
  <artifactId>infinispan-hibernate-cache</artifactId>
  <version>${version.infinispan}</version>
</dependency>
```

### *Hibernate 5.1*

```
<dependency>
  <groupId>org.infinispan</groupId>
  <artifactId>infinispan-hibernate-cache-v51</artifactId>
</dependency>
```

### *Hibernate version 5.0 and earlier*

The Infinispan cache provider is shipped by Hibernate. Documentation and Maven coordinates are located in the [Hibernate documentation](#).

## 1.2. Enabling second-level caches

Apart from Infinispan specific configuration, it's worth noting that enabling second cache requires some changes to the descriptor file (`persistence.xml` for JPA or `application.properties` for Spring). To use second level cache, you first need to enable the second level cache so that entities and/or collections can be cached:

Table 1. Enable second-level cache

JPA	<code>&lt;property name="hibernate.cache.use_second_level_cache" value="true"/&gt;</code>
Spring	<code>spring.jpa.properties.hibernate.cache.use_second_level_cache=true</code>

To select which entities/collections to cache, first annotate them with `javax.persistence.Cacheable`. Then make sure shared cache mode is set to `ENABLE_SELECTIVE`:

Table 2. Enable selective shared cached mode

JPA	<code>&lt;shared-cache-mode&gt;ENABLE_SELECTIVE&lt;/shared-cache-mode&gt;</code>
Spring	<code>spring.jpa.properties.javax.persistence.sharedCache.mode=ENABLE_SELECTIVE</code>



This is the most common way of selecting which entities/collections to cache. However, there are alternative ways to which are explained in the [Hibernate documentation](#).

Optionally, queries can also be cached but for that query cache needs to be enabled:

Table 3. Enable query cache

JPA	<code>&lt;property name="hibernate.cache.use_query_cache" value="true"/&gt;</code>
Spring	<code>spring.jpa.properties.hibernate.cache.use_query_cache=true</code>



As well as enabling query cache, forcing a query to be cached requires the query to be made cacheable. For example, for JPA queries: `query.setHint("org.hibernate.cacheable", Boolean.TRUE)`.

The best way to find out whether second level cache is working or not is to inspect the statistics. By inspecting the statistics you can verify if the cache is being hit, if any new data is stored in cache... etc. Statistics are disabled by default, so it is recommended that you enable statistics:

Table 4. Enable statistics

JPA	<code>&lt;property name="hibernate.generate_statistics" value="true" /&gt;</code>
Spring	<code>spring.jpa.properties.hibernate.generate_statistics=true</code>

## 1.3. Deployment scenarios

How to configure Infinispan to be the second level cache provider varies slightly depending on the deployment scenario:

### 1.3.1. Single-node standalone Hibernate application

In standalone library mode, a JPA/Hibernate application runs inside a Java SE application or inside containers that don't offer Infinispan integration.

Enabling Infinispan second level cache provider inside a JPA/Hibernate application that runs in single node is very straightforward. First, make sure the Hibernate Infinispan cache provider is available in the classpath. Then, modify the `persistence.xml` to include these properties:

```
<!-- Use Infinispan second level cache provider -->
<property name="hibernate.cache.region.factory_class" value="infinispan"/>
<!--
    Force using local configuration when only using a single node.
    Otherwise a clustered configuration is loaded.
-->
<property name="hibernate.cache.infinispan.cfg"
    value="org/infinispan/hibernate/cache/commons/builder/infinispan-configs-
local.xml"/>
```

By default when running standalone, the Infinispan second-level cache provider uses an Infinispan configuration that's designed for clustered environments. However, Infinispan also provides a configuration designed for local, single node, environments. To enable that configuration, set `hibernate.cache.infinispan.cfg` to `org/infinispan/hibernate/cache/commons/builder/infinispan-configs-local.xml` value. You can find more about the configuration check the [Default Local Configuration](#) section.

A simple tutorial showing how to use Infinispan as Hibernate cache provider in a standalone application can be found [here](#).

### 1.3.2. Single-node standalone Spring application

Using Hibernate within Spring applications is a very common use case. In this section you will learn what you need to do configure Hibernate within Spring to use Infinispan as second-level cache provider.

As in the previous case, start by making sure that Hibernate Infinispan Cache provider is available in the classpath. Then, modify `application.properties` file to contain:

```
# Use Infinispan second level cache provider
spring.jpa.properties.hibernate.cache.region.factory_class=infinispan
#
# Force using local configuration when only using a single node.
# Otherwise a clustered configuration is loaded.
spring.jpa.properties.hibernate.cache.infinispan.cfg=org/infinispan/hibernate/cache/co
mmons/builder/infinispan-configs-local.xml
```

By default when running standalone, the Infinispan second-level cache provider uses an Infinispan configuration that's designed for clustered environments. However, Infinispan also provides a

configuration designed for local, single node, environments. To enable that configuration, set `spring.jpa.properties.hibernate.cache.infinispan.cfg` to `org/infinispan/hibernate/cache/commons/builder/infinispan-configs-local.xml` value. You can find more about the configuration check the [Default Local Configuration](#) section.

A simple tutorial showing how to use Infinispan as Hibernate cache provider in a Spring application can be found [here](#).

### 1.3.3. Single-node WildFly application

In WildFly, Infinispan is the default second level cache provider for JPA/Hibernate. This means that when using JPA in WildFly, region factory is already set to `infinispan`. Infinispan's configuration is located in WildFly's `standalone.xml` file. It follows the same settings explained in [Default Local Configuration](#) section.



When running in WildFly, do not set `hibernate.cache.infinispan.cfg`. The configuration of the caches comes from WildFly's configuration file.

Several aspects of the Infinispan second level cache provider can be configured directly in `persistence.xml`. This means that some of those tweaks do not require changing WildFly's `standalone.xml` file. You can find out more about these changes in the [Configuration Properties](#) section.

So, to enable Hibernate to use Infinispan as second-level cache, all you need to do is enable second-level cache. This is explained in detail in the introduction of this chapter.

A simple tutorial showing how to use Infinispan as Hibernate cache provider in a WildFly application can be found [here](#).

### 1.3.4. Multi-node standalone Hibernate application

When running a JPA/Hibernate in a multi-node environment and enabling Infinispan second-level cache, it is necessary to cluster the second-level cache so that cache consistency can be guaranteed. Clustering the Infinispan second-level cache provider is as simple as adding the following property to the `persistence.xml` file:

```
<!-- Use Infinispan second level cache provider -->
<property name="hibernate.cache.region.factory_class" value="infinispan"/>
```

The default Infinispan configuration used by the second-level cache provider is already configured to work in a cluster environment, so no need to add any extra properties. You can find more about the configuration check the [Default Cluster Configuration](#) section.

### 1.3.5. Multi-node standalone Spring application

If interested in running a Spring application that uses Hibernate and Infinispan as second level cache, the cache needs to be clustered. Clustering the Infinispan second-level cache provider is as simple as adding the following property to the `application.properties` file:

```
# Use Infinispan second level cache provider
spring.jpa.properties.hibernate.cache.region.factory_class=infinispan
```

The default Infinispan configuration used by the second-level cache provider is already configured to work in a cluster environment, so no need to add any extra properties. You can find more about the configuration check the [Default Cluster Configuration](#) section.

### 1.3.6. Multi-node WildFly application

As mentioned in the single node WildFly case, Infinispan is the default second level cache provider for JPA/Hibernate when running inside WildFly. This means that when using JPA in WildFly, region factory is already set to `infinispan`.

When running WildFly multi-node clusters, it is recommended that you start off by using `clustered.xml` configuration file. Within this file you can find Hibernate Infinispan caches configured with the correct settings to work in a clustered environment. You can find more about the configuration check the [Default Cluster Configuration](#) section.

Several aspects of the Infinispan second level cache provider can be configured directly in `persistence.xml`. This means that some of those tweaks do not require changing WildFly's `standalone-ha.xml` file. You can find out more about these changes in the [Configuration Properties](#) section.

So, to enable Hibernate to use Infinispan as second-level cache, all you need to do is enable second-level cache. Enabling second-level cache is explained in detail in the introduction of this chapter.

## 1.4. Configuration reference

This section is dedicated at explaining configuration in detail as well as some extra configuration options.

### 1.4.1. Default local configuration

Infinispan second-level cache provider comes with a configuration designed for local, single node, environments. These are the characteristics of such configuration:

Entities, collections, queries and timestamps are stored in non-transactional local caches.

Entities and collections query caches are configured with the following eviction settings:

- Eviction wake up interval is 5 seconds.
- Max number of entries are 10,000.
- Max idle time before expiration is 100 seconds.
- Default eviction algorithm is LRU, least recently used.

You can change these settings on a per entity or collection basis or per individual entity or collection type. More information in the [Configuration Properties](#) section below.



No eviction/expiration is configured for timestamp caches, nor it's allowed.

### 1.4.2. Default cluster configuration

Infinispan second-level cache provider default configuration is designed for multi-node clustered environments. The aim of this section is to explain the default settings for each of the different global data type caches (entity, collection, query and timestamps), why these were chosen and what are the available alternatives. These are the characteristics of such configuration:

#### *Entities and Collections*

By default all *entities and collections are configured to use a synchronous invalidation* as clustering mode. Whenever a new *entity or collection is read from database* and needs to be cached, *it's only cached locally* in order to reduce intra-cluster traffic. This option can be changed so that entities/collections are cached cluster wide, by switching the entity/collection cache to be replicated or distributed. How to change this option is explained in the [Configuration Properties](#) section.



When data read from the database is put in the cache, with replicated or distributed caches, the data is propagated to other nodes using asynchronous communication. In the presence of concurrent database loads, one operation will succeed while others might fail (silently). This is fine because they'd all be trying to put the same data loaded from the database. This has the side effect that under these circumstances, the cache might not be up to date right after making the JPA call that leads to the database load. However, the cache will eventually contain the data loaded, even if it happens after a short delay.

All *entities and collections are configured to use a synchronous invalidation* as clustering mode. This means that when an entity is updated, the updated cache will send a message to the other members of the cluster telling them that the entity has been modified. Upon receipt of this message, the other nodes will remove this data from their local cache, if it was stored there. This option can be changed so that both local and remote nodes contain the updates by configuring entities or collections to use a replicated or distributed cache. With replicated caches all nodes would contain the update, whereas with distributed caches only a subset of the nodes. How to change this option is explained in the [Configuration Properties](#) section.

All *entities and collections have initial state transfer disabled* since there's no need for it.

Entities and collections are configured with the following eviction settings. You can change these settings on a per entity or collection basis or per individual entity or collection type. More information in the [Configuration Properties](#) section below.

- Eviction wake up interval is 5 seconds.
- Max number of entries are 10,000.
- Max idle time before expiration is 100 seconds.
- Default eviction algorithm is LRU, least recently used.

#### *Queries*

Assuming that query caching has been enabled for the persistence unit (see chapter introduction),

the query cache is configured so that *queries are only cached locally*. Alternatively, you can configure query caching to use replication by selecting the **replicated-query** as query cache name. However, replication for query cache only makes sense if, and only if, all of these conditions are true:

- Performing the query is quite expensive.
- The same query is very likely to be repeatedly executed on different cluster nodes.
- The query is unlikely to be invalidated out of the cache



Hibernate must aggressively invalidate query results from the cache any time any instance of one of the entity types targeted by the query. All such query results are invalidated, even if the change made to the specific entity instance would not have affected the query result. For example: the cached result of **SELECT id FROM cars where color = 'red'** is thrown away when you call **INSERT INTO cars VALUES ..., color = 'blue'**. Also, the result of an update within a transaction is not visible to the result obtained from the query cache.

*query cache uses the same eviction/expiration settings as for entities/collections.*

*query cache has initial state transfer disabled.* It is not recommended that this is enabled.

Up to Hibernate 5.2 both transactional and non-transactional query caches have been supported, though non-transactional variant is recommended. Hibernate 5.3 drops support for transactional caches, only non-transactional variant is supported. If the cache is configured with transactions this setting is ignored and warning is logged.

### Timestamps

The *timestamps cache* is configured with *asynchronous replication* as clustering mode. Local or invalidated cluster modes are not allowed, since all cluster nodes must store all timestamps. As a result, *no eviction/expiration is allowed for timestamp caches either*.



Asynchronous replication was selected as default for timestamps cache for performance reasons. A side effect of this choice is that when an entity/collection is updated, for a very brief period of time stale queries might be returned. It's important to note that due to how Infinispan deals with asynchronous replication, stale queries might be found even query is done right after an entity/collection update on same node.



Hibernate must aggressively invalidate query results from the cache any time any instance of one of the entity types is modified. All cached query results referencing given entity type are invalidated, even if the change made to the specific entity instance would not have affected the query result. The timestamps cache plays here an important role - it contains last modification timestamp for each entity type. After a cached query results is loaded, its timestamp is compared to all timestamps of the entity types that are referenced in the query. If any of these is higher, the cached query result is discarded and the query is executed against DB. This requires synchronization of the wall clock across the cluster to work as expected.

### 1.4.3. Configuration properties

As explained above, Infinispan second-level cache provider comes with default configuration in `infinispan-config.xml` that is suited for clustered use. If there's only single JVM accessing the DB, you can use more performant `infinispan-config-local.xml` by setting the `hibernate.cache.infinispan.cfg` property. If you require further tuning of the cache, you can provide your own configuration. Caches that are not specified in the provided configuration will default to `infinispan-config.xml` (if the provided configuration uses clustering) or `infinispan-config-local.xml`.



It is not possible to specify the configuration this way in WildFly. Cache configuration changes in WildFly should be done either modifying the cache configurations inside the application server configuration, or creating new caches with the desired tweaks and plugging them accordingly. See examples below on how entity/collection specific configurations can be applied.

#### Use custom Infinispan configuration

```
<property
  name="hibernate.cache.infinispan.cfg"
  value="my-infinispan-configuration.xml" />
```



If the cache is configured as transactional, Infinispan cache provider automatically sets transaction manager so that the TM used by Infinispan is the same as TM used by Hibernate.

Cache configuration can differ for each type of data stored in the cache. In order to override the cache configuration template, use property `hibernate.cache.infinispan.data-type.cfg` where `data-type` can be one of:

- **entity**: Entities indexed by `@Id` or `@EmbeddedId` attribute.
- **immutable-entity**: Entities tagged with `@Immutable` annotation or set as `mutable=false` in mapping file.
- **naturalid**: Entities indexed by their `@NaturalId` attribute.
- **collection**: All collections.
- **timestamps**: Mapping *entity type* → *last modification timestamp*. Used for query caching.
- **query**: Mapping *query* → *query result*.
- **pending-puts**: Auxiliary caches for regions using invalidation mode caches.

For specifying cache template for specific region, use region name instead of the `data-type`:

### Use custom cache template

```
<property
  name="hibernate.cache.infinispan.entities.cfg"
  value="custom-entities" />
<property
  name="hibernate.cache.infinispan.query.cfg"
  value="custom-query-cache" />
<property
  name="hibernate.cache.infinispan.com.example.MyEntity.cfg"
  value="my-entities" />
<property
  name="hibernate.cache.infinispan.com.example.MyEntity.someCollection.cfg"
  value="my-entities-some-collection" />
```

### Use custom cache template in WildFly

When applying entity/collection level changes inside JPA applications deployed in WildFly, it is necessary to specify deployment name and persistence unit name (separated by # character):

```
<property
  name=
"hibernate.cache.infinispan._war_or_ear_name_#_unit_name_.com.example.MyEntity.cfg"
  value="my-entities" />
<property
  name=
"hibernate.cache.infinispan._war_or_ear_name_#_unit_name_.com.example.MyEntity.someCol
lection.cfg"
  value="my-entities-some-collection" />
```



Cache configurations are used only as a template for the cache created for given region. Usually each entity hierarchy or collection has its own region



Except for eviction/expiration settings, it is highly recommended not to deviate from the template configuration settings.

Some options in the cache configuration can also be overridden directly through properties. These are:

- `hibernate.cache.infinispan.something.eviction.strategy`: Available options are `NONE`, `LRU` and `LIRS`.
- `hibernate.cache.infinispan.something.eviction.max_entries`: Maximum number of entries in the cache.
- `hibernate.cache.infinispan.something.expiration.lifespan`: Lifespan of entry from insert into cache (in milliseconds).
- `hibernate.cache.infinispan.something.expiration.max_idle`: Lifespan of entry from last read/modification (in milliseconds).

- `hibernate.cache.infinispan.something.expiration.wake_up_interval`: Period of thread checking expired entries.
- `hibernate.cache.infinispan.statistics`: Globally enables/disable Infinispan statistics collection, and their exposure via JMX.

Example:

```
<property name="hibernate.cache.infinispan.entity.eviction.strategy"
  value= "LRU"/>
<property name="hibernate.cache.infinispan.entity.eviction.wake_up_interval"
  value= "2000"/>
<property name="hibernate.cache.infinispan.entity.eviction.max_entries"
  value= "5000"/>
<property name="hibernate.cache.infinispan.entity.expiration.lifespan"
  value= "60000"/>
<property name="hibernate.cache.infinispan.entity.expiration.max_idle"
  value= "30000"/>
```

With the above configuration, you're overriding whatever eviction/expiration settings were defined for the default entity cache name in the Infinispan cache configuration used. This happens regardless of whether it's the default one or user defined. More specifically, we're defining the following:

- All entities to use LRU eviction strategy
- The eviction thread to wake up every 2 seconds (2000 milliseconds)
- The maximum number of entities for each entity type to be 5000 entries
- The lifespan of each entity instance to be 1 minute (60000 milliseconds).
- The maximum idle time for each entity instance to be 30 seconds (30000 milliseconds).

You can also override eviction/expiration settings on a per entity/collection type basis. This allows overrides that only affects a particular entity (i.e. `com.acme.Person`) or collection type (i.e. `com.acme.Person.addresses`). Example:

```
<property name="hibernate.cache.infinispan.com.acme.Person.eviction.strategy"
  value= "LIRS"/>
```

Inside of WildFly, same as with the entity/collection configuration override, eviction/expiration settings would also require deployment name and persistence unit information (a working example can be found [here](#)):

```

<property name=
"hibernate.cache.infinispan._war_or_ear_name_#_unit_name_.com.acme.Person.eviction.str
ategy"
    value= "LIRS"/>
<property name=
"hibernate.cache.infinispan._war_or_ear_name_#_unit_name_.com.acme.Person.expiration.l
ifespan"
    value= "65000"/>

```

## 1.5. Cache strategies

Infinispan cache provider supports all Hibernate cache strategies: `transactional`, `read-write`, `nonstrict-read-write` and `read-only`.

Integrations with Hibernate 4.x required `transactional` caches and in integrations with Hibernate & 5.2 `transactional` caches are supported (in JTA environment). However for all 5.x versions `non-transactional` caches are preferred. With Hibernate 5.3 the support for transactional caches has been dropped completely, and both `read-write` and `transactional` use the same implementation. Infinispan provides the same consistency guarantees for both `transactional` and `read-write` strategies, use of transactions is considered an implementation detail.

In integrations with Hibernate 5.2 or lower the actual setting of cache concurrency mode (`read-write` vs. `transactional`) is not honored on invalidation caches, the appropriate strategy is selected based on the cache configuration (`non-transactional` vs. `transactional`).

Support for *replicated/distributed* caches for `read-write` and `read-only` strategies has been added during 5.x development and this requires exclusively *non-transactional configuration*. Also eviction should not be used in this configuration as it can lead to consistency issues. Expiration (with reasonably long max-idle times) can be used.

`Nonstrict-read-write` strategy is supported on *non-transactional distributed/replicated* caches, but the eviction should be turned off as well. In addition to that, the entities must use versioning. This means that this strategy cannot be used for caching natural IDs (which are never versioned). This mode mildly relaxes the consistency - between DB commit and end of transaction commit a stale read may occur in another transaction. However this strategy uses less RPCs and can be more performant than the other ones.

`Read-only` mode is supported in all configurations mentioned above but use of this mode currently does not bring any performance gains.

The available combinations are summarized in table below:

Table 5. Cache concurrency strategy/cache mode compatibility table

Concurrency strategy	Cache transactions	Cache mode	Eviction
transactional	& 5.2 transactional	invalidation	yes

Concurrency strategy	Cache transactions	Cache mode	Eviction
transactional	&ge; 5.3 non-transactional	invalidation	yes
read-write	non-transactional	invalidation	yes
read-write	non-transactional	distributed/replicated	no
nonstrict-read-write	non-transactional	distributed/replicated	no

Changing caches to behave different to the default behaviour explained in previous section is explained in the [Configuration Properties](#) section.



Use of transactional caches is possible only in JTA environment. Hibernate supports JDBC-only transactions but Infinispan transactional caches do not integrate with these. Therefore, in non-JTA environment the only option is to use **read-write**, **nonstrict-read-write** or **read-only** on non-transactional cache. Configuring the cache as transactional in non-JTA can lead to undefined behaviour.

*Stale read with **nonstrict-read-write** strategy*

```
A=0 (non-cached), B=0 (cached in 2LC)
TX1: write A = 1, write B = 1
TX1: start commit
TX1: commit A, B in DB
TX2: read A = 1 (from DB), read B = 0 (from 2LC) // breaks transactional atomicity
TX1: update A, B in 2LC
TX1: end commit
Tx3: read A = 1, B = 1 // reads after TX1 commit completes are consistent again
```

## 1.6. Using minimal puts

Hibernate offers a configuration option **hibernate.cache.use\_minimal\_puts** which is off by default in Infinispan implementation. This option checks if the cache contains given key before updating the value from database (put-from-load) and omits the update if the cached value is already present. When using invalidation caches it makes sense to keep this off as the put-from-load is local node-only and silently fails if the entry is locked. With replicated/distributed caches the update is applied to remote nodes, even if the local node already contains the entry, and this has higher performance impact, so it might make sense to turn this option on and avoid updating the cache.